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COSMOLOGY.—*The physical universe.*[1] HERBERT DINGLE, Imperial College of Science and Technology, London. (Communicated by HUGH L. DRYDEN.)

The word *universe* is used in so many senses, even within the field of scientific discussion, that it is the duty of anyone who uses the word to state what he intends it to represent. For the purpose of this lecture, *the universe* will mean the totality of physical existence; that is to say, the matter and energy existing in space considered as a whole. In using this expression, I wish at present to leave open the questions whether space is infinite, and whether if so, it contains an infinite amount of matter. Whatever the answers to these questions, we can still discuss the universe because even infinity can be treated *as a whole;* the infinite is not necessarily the indefinite. A simple example of this may be helpful. The series of numbers is infinite and it is therefore impossible for all numbers to be thought of individually in a lifetime: nevertheless, when a word is uttered we know immediately whether it represents a number or not. 6,425,814 is a number; a horse is not: it is not necessary to go through the series member by member to verify this. Hence infinity is not inapprehensible: we can make assertions about it and distinguish its contents from what lies outside it. It is the character of the whole, and not the catalogue of the parts that will be the subject of our discussion. As we shall see, the modern investigation of the universe is sometimes inconsistent in this respect: it professes to speak of the whole, but does so in terms incompatible with its profession. That, however, is an anticipation.

There is another preliminary remark to be made. A complete discussion of the physical universe would include an account of its mechanical and thermal properties, for both of these are physical in character. Time will not permit of this, however, and, as a matter of fact, in the present state of science, these two aspects of the subject are quite sharply divided. We can describe the mechanical properties of a system (whether or not it is the universe I will not presume to

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say), including its history from a hypothetical beginning to a hypothetical end, without any reference at all to the exchange of heat between its parts which is so important from the physiological point of view, for instance; and in such descriptions we usually speak of "the universe" without pausing to remark that it is only the mechanical aspect of the universe that we are considering. It is to that aspect that I shall confine myself in this lecture. Problems concerning the alleged *running-down of the universe*, important as they are, will be outside our scope.

The universe has come prominently to the fore in astronomical discussions in the last few years, for reasons which we shall see, but it would be a mistake to regard the study of the universe as essentially a modern subject. It is, in fact, almost the most ancient of subjects, and has undergone many vicissitudes in the course of scientific history; and one of the chief objects of this lecture is to place the modern developments in a historical setting. There is a common idea that science, in its gradual progress, has at last, for the first time, caught a glimpse of the universe, its previous history having been concerned entirely with the partial aspects of things presented to us by the contents of our own neighborhood. That is emphatically not the case. On the contrary, there is exhibited throughout history a remarkable proneness among investigators to regard their horizon as the boundary of existence, and the annals of astronomy show us that no sooner does man realize that what he once thought was the whole is only a part, than he immediately invests the larger conception to which he has attained with the same illusory finality that formerly distorted the old. This is not a characteristic of the past only. Many modern investigators are as sure as ever their forerunners were that they have at last discerned the universe. It is largely in order to combat this attitude that I have elected to treat the subject historically, and if I say some things that have been familiar to you from childhood, you will understand that I do not say them in order to convey information, but to indicate the proper background against which to see more modern ideas.

Early astronomy was simply cosmology—no more and no less. The Earth was fixed at the centre of the universe, and the heavenly bodies were points on a celestial sphere or spheres which revolved regularly round the Earth. Certain complications were introduced into this mechanism to account for the details of planetary motions, but the essential point for our purpose is that the only subject of study was the whole system of heavenly motions, and not at all the char-

acteristics of any part of the system. The time had not arrived when the Sun, for instance, could be the object of individual study. Man contemplated the whole universe, beyond which was the heaven of heavens. The scheme in principle was very simple, and all that astronomy was concerned with was its adaptation to the observations of planetary positions and its application to the practical needs of man.

These, however, proved to be surprisingly troublesome problems, and by the time of the Renaissance the elaboration of the scheme had become so complex that thoughtful minds began to suspect that some fundamental reconstruction was needed. As everyone knows, this was begun by Copernicus. The Earth was removed from its central position and placed among the planets which revolved round the Sun. The change from a geocentric to a heliocentric system is, of course, one of the greatest advances in the history of thought, extending far beyond the particular cosmological example which introduced it, but even more important than a change of viewpoint was the introduction of the idea of infinite space. With a central Earth and a spherical firmament, cosmology came to a natural end at the frontiers of theology: there was no need of infinity, and the idea was not entertained. But when the firmament was destroyed, and when, shortly afterwards, it appeared that the number of visible stars could be multiplied indefinitely by increasing telescopic power, infinity forced itself on men's attention, and the conception of an unlimited population of stars became the natural successor of the homely, limited universe of previous centuries.

With this change, astronomy, in the narrower sense of the word, was born. The universe had apparently passed beyond the reach of human thought. At the same time, its separate units had entered the reach of human thought. The telescope provided the means of studying individual bodies, and so, by force of necessity, the contemplation of the whole gave way before the examination of the part. For a brief spell cosmology ceased to exist.

It was reestablished by Newton, though in a new and previously unknown form. Newton made no attempt to grasp the aggregate of stellar existences, but he showed how to discover characteristics of the whole, even though that whole could be only partially observed. His conception of universal law restored cosmology on a new basis. He introduced the idea of principles inherent in the whole and fully expressed in every part—principles which could be deduced from partial observation and then applied to the whole. His laws of motion and

gravitation were of this character. They were statements, not of the actual, material structure of the universe, but of something which characterized the universe whatever its material structure might be. Cosmology therefore changed from a description of the body of nature to a search for the soul.

This, to be sure, involved assumptions. Before you can extend a generalization from a few observations to the whole of material existence you must postulate that the whole of material existence is in fact a *universe*, having universal characteristics. If that is not true, your laws of motion or gravitation or what not may hold in your own neighborhood, but not elsewhere. Furthermore, you must assume that your observations of a limited region are accurate enough to enable you to apply your deductions throughout the whole—possibly infinite—extent of space; you must assume, not only that there *are* universal laws, but that you have actually found them. These assumptions are worth noting because they have perhaps been too generally ignored. When, by *universe*, you mean, as in the old days, a particular system of material bodies, there are no such assumptions; cosmology is simply a statement of what you observe. But when you are forced to give up the attempt to observe the whole, but still presume to speak of a *universe* because the part you observe shows mutual relations between its parts, it is well to bear in mind that you have no longer the solid ground of primary fact beneath your feet, but an idea which, however, plausible, is still of an essentially different character from the basis of the cosmology of old.

There is no harm in assumptions, however, provided their existence is not forgotten. Accordingly, Newton's laws were accepted and their implications examined. One would hardly expect that laws which, by hypothesis, are held to be true whatever the material contents of space, would be able to give any information about those contents, yet this turned out to be possible. It became clear that if Newton's laws were actually universal, there could not be an infinite space in which stars were uniformly distributed, no matter how coarse the scale considered or how thin the distribution postulated. Since, by that time, the idea that space was infinite had become almost axiomatic, this meant that as one receded to distant places one would at last pass beyond the region of matter into emptiness: the universe of matter would be an island in an infinite ocean of vacuity. This was deduced from the fact that in a region of uniform material density, the mass of matter in a sphere centred at the Earth would be proportional to the cube of the radius, whereas the effect of distance on the gravi-

tational attraction of this mass on the Earth would be inversely proportional to the square of the radius. Hence Newton's law of gravitation would require that the gravitational effect at the Earth of the matter in such a sphere would, on the whole, increase with the radius, and so, with an infinite distribution of matter, would become infinite which was held to be contrary to observation.

I am not going to discuss this argument, because I am now simply describing history, not criticising it. It might be well, however, to say a word or two about the meaning of the coarseness of the scale of density considered. It is obvious, of course, that on the fine scale, the distribution of matter is far from uniform. The density of the Earth is much greater than that of water, and the density just outside it is almost zero. Two volumes of, say 1 cc. each may therefore contain very different amounts of matter, depending on the particular cubic centimeters chosen. If, however, we compared two volumes of, say, a billion cubic light years, we might find that they contained approximately equal amounts of matter; and if not, it might still be that much larger units of volume would give us a uniform distribution. Two volumes of 1 cubic millimetre in a sponge may differ widely in material content, for one may be in a hole and the other in the material of the sponge: two volumes of 1 cubic inch, however, would contain approximately equal amounts, so that there is a scale on which the sponge is a uniform distribution of matter. Since, in the cosmological problem we are, by hypothesis, dealing with infinite space, all finite units are infinitesimal, so we are justified in considering units of any finite size at all, and if we can find a size which will give us uniformity of density, the argument applies.

Now the conclusion of the argument was held to be unsatisfactory. It was not philosophically satisfying to think that a particular bit of space was occupied by stars while the rest was empty. Minds which had awakened from a geocentric illusion were apt to regard with suspicion any idea which tended to assign them a unique position in space, and so it was felt that somehow space ought to be filled uniformly—in other words, the universe should be homogeneous. Apparently, however, this could not be secured without abandoning the universality of Newton's law of gravitation, and this also was repugnant. No solution of the difficulty presented itself, and so the matter rested.

Meanwhile, telescopes and spectroscopes had been busy increasing the extent and accuracy of our knowledge of the contents of our own neighborhood. The solar system belonged to a vast organization of

stars which appeared to be one of many such organizations—the spiral nebulae. The evidence for this was rather slender at first, but increased later, and at the time which we have reached in the development of theoretical ideas, it had captured the imaginations rather than the intellects of astronomers. Despite definite indications that our stellar system was thinning out with distance from the Sun, as the gravitational argument required, the spiral nebulae were held to be *island universes* which, on the coarse scale, might provide the homogeneity of material distribution which instinct demanded. Insofar as the unsettled ideas of the time can be said to have presented a definite aspect, it was either that of a single system of material bodies in a surrounding infinite void, or that of a multitude of such systems with an unknown distribution throughout that void. Whichever idea was held, however, it was regarded as an idea of the universe. The possibility that what we observed was too small to be *typical* in any degree of the whole was scarcely accorded even lip-service.

Such was the position at the advent of relativity. This affected our problem in two ways. In the first place, it showed that we could not adequately consider the distribution of matter in space without considering its distribution in time also—a fact which is often falsely expressed by the statement that time and space are identical. And, in the second place, it displaced Newton's law of gravitation by another which did not prohibit the possibility that space was completely filled by a homogeneous distribution of matter. I am not going to discuss the principle of relativity itself but I want to say a few words on each of these points.

The inseparability of time and space is easier to realize in relation to the universe than in any other relation, because of the greatness of the scale. It all depends on the fact that we know of no physical means of communication between separated points of space which is more rapid than light. Between terrestrial events light passes practically instantaneously, so that we can say with sufficient exactness that a thing happens when we see it. But when we see an event on even the nearest spiral nebula, we know that that event happened nearly a million years ago. We can theoretically, if we wish, determine what terrestrial events were *simultaneous* with it, but when we are dealing with such intervals, simultaneity loses its interest. We are much more concerned with what we can see now in the nebula than with what is happening there now, which will not be revealed to us for nearly a million years. Hence the structure of the universe

at any one time is no longer the object of our investigation. Instead, we take history and structure together in a union which relates our present observations with one another and relegates to the background the results of calculations concerning conceptual simultaneous happenings. That is all that the amalgamation of time and space means, and if one thinks of it in terms of these large-scale phenomena instead of terrestrial events it ceases to be mystical and one is saved from the illusion that somehow time and space are the same, despite our knowledge that they are very different.

The possibility that space might be filled homogeneously with matter without violating known facts arises from the possibility, afforded by the new law of gravitation, that space might be finite, though unbounded. This is another of the so-called mysteries of relativity, but it is not at all incomprehensible I think, if it is approached in the right way. The difficulty which one feels is that if the matter of the universe is contained in a finite space, one can always imagine an infinite space outside that finite region, so that it is not accurate to say that *space* is finite.

Very well, let the surrounding infinite space be imagined. We then have a homogeneous sphere, let us say, of matter surrounded by infinite emptiness. This sphere, of course, consists of the stars and nebulae that we see around us, together with all that might be beyond the present reach of our telescopes; and we are somewhere in the midst of it. Now let us try to send some matter outside this region into the enveloping void. We find this impossible, because the law of gravitation is such that the matter cannot escape;[2] it always returns like a stone thrown into the air. It is possible, of course, to project a stone fast enough to escape from the Earth altogether, but the laws of motion and gravitation in the Einstein universe are such that it is impossible for the stone to get free into our imaginary void. There is nothing difficult to conceive in that: it simply means that nature provides no method of projecting a body fast enough to escape from this system of bodies which we call the universe.

We might imagine, however, that we can *see* outside the system. But that is impossible also. If we project a beam of light upwards, it will be attracted by the rest of the universe and bent back so that it cannot escape. Furthermore, if we were situated at the very boundary of our sphere we could still look upwards and see only light from stars beneath us. The stars would appear to be above us because their light

[2] I am now describing the original static Einstein universe; we will consider later the more recently conceived *expanding* universe.

would enter our eyes in a downward direction, but the stars themselves would not be there. If we travelled along their light we should go upwards a little, and then turn round until at last we should enter the star from which the light came, at a place somewhere inside the system. This also is not inconceivable; it is simply an example of a fact very familiar to everyday experience. When we see the Sun on the horizon in the evening, it has already set: its light is bent by the atmosphere of the Earth so that we see the Sun although it is already below our level. In precisely the same way, though from a different cause, the stars which our boundary observer would see above him would be below his feet.

Now let us notice two things. Since nothing—neither light nor matter—can escape from our universe, and we get no indication of anything outside, we can dispense with the notion of a surrounding emptiness. We can go on thinking about it if we like, but if so we are confusing our thought, because we can get no knowledge of it: everything we can see or know belongs to our own system of stars. Hence, since astronomers do not wish to load their minds with ideas which serve no purpose, they discard it, and call space simply the region which is accessible to observation. The surrounding infinity has no scientific existence: it is simply an illusion, necessary in an immature stage of thought, just as the propositions of arithmetic have at first to be incarnated in problems about apples or pears. When we know the principles of the problem we can dispense with the part which does not enter into the solution.

The second thing to notice is that since our hypothetical observer at the boundary of the system sees stars above him just as an inside observer does, he cannot tell that he is at the boundary. Detailed considerations show, in fact, that his view would be indistinguishable from that of the inside observer, and therefore there is nothing to be gained by saying that he rather than the other is on the boundary. The statement previously made that the stars were "beneath his feet" would mean nothing to him: that would be the appearance to a hypothetical observer outside the universe. We have already dispensed with the outside space which is all that could give a meaning to a boundary, and so it follows that there is no boundary. Wherever you are in the universe you see the same kind of spectacle and have the same freedom and limitation of movement. Hence one part of the universe is just like another: the universe is homogeneous and unbounded. It is nevertheless finite because you can, in principle, count the stars in it and get a finite number. Also, you can travel about

and, in principle, survey the whole. The whole difficulty of conceiving of finite unbounded space is therefore that of discarding artificial aids to thought: when the lesson is learned, the parable is no longer necessary.

The universe I have described is the famous Einstein universe of the early days of relativity. At that time the remarkable phenomenon of the recession of the spiral nebulae[3] was not known. It has since been discovered that these objects are receding from us (i.e., from our whole stellar system, for we are now speaking on the largest scale consistent with our knowledge) at speeds proportional to their distances: the most distant nebula now known to take part in this recession is some 230 million light-years away, and it is moving with a speed of 40,000 kilometers a second. Of course, there is much uncertainty about these measurements—not only with regard to the actual figures, but also with regard to the interpretation of the phenomena which we call *distance* and *velocity*. The velocities are measured by the displacements of spectrum lines, and these may have some unknown cause in objects so exceptional and unfamiliar as those which we are considering. Nevertheless, there is no valid reason for rejecting the ordinary interpretation. Many feel inclined to do so because of the enormous velocities involved, but that is pure prejudice. There is no reason at all why nebulae should not move at such speeds, and indeed we ought to expect that the qualities they exhibit will differ in important respects from those to which our provincial minds are accustomed. When we have, as here, to choose between exceptional behavior of bodies and exceptional laws of nature, the former is certainly the choice which is more in accord with the general practice of science. If, then, we reject unscientific expectation as a sufficient reason for doubting the motions of the nebulae, we are left with only the healthy scepticism which does not forget that it is employing speculative building material, but nevertheless goes on building.

Relativity mechanics is quite consistent with a universal nebular recession; indeed, there is a sense in which it predicted the phenomenon, though only as one among other possibilities. The mutual support of observation and theory therefore gives considerable plausibility to the idea that we are at last in touch with the universe itself, for the mechanical system which relativity describes as expanding is one which is completely self-contained. Like the rejected Einstein universe, it has no space outside itself which has any scientific mean-

[3] The term, *spiral nebulae* is used to denote the extra-galactic nebulae generally· many of them, of course, do not show a spiral structure.

ing, notwithstanding the fact that we find it difficult to conceive how a system can expand when there is nothing for it to expand into. This difficulty appears to be at bottom a play upon the word *nothing*, for actually *nothing* is just what we want to make the idea credible; if there were *something* there, expansion might be prevented. To put it in another way, space becomes significant only when the system has expanded so as to include it: whatever is not included at any instant has no significance, for it is quite without influence on the system at that instant. At a later instant, when the system contains more space, we are inclined to think of the added amount as having previously existed outside, but we cannot identify that *added* amount. It is not something which we can label and say, "This part has been in the universe all the time, and this part has only just come in." All we can discover from observation is that if we measure the distance between two nebulae at two different instants, the distance will be greater at the later instant. We do not observe a boundary constantly moving outwards; we simply observe nebulae receding all around us. Consequently the *expansion* of the universe is only a picturesque expression of a characteristic of our measurements. If we try to picture the universe as an isolated system from which we can withdraw and observe it as a whole, we feel compelled to insist on a surrounding space in which it can be isolated. If we give this up and keep to the actual facts of the case, which are simply concerned with relations between our measurements, our difficulty vanishes.

I think the difficulties of understanding the modern views of space are enhanced by the idea of *space curvature*, which is so commonly talked about. The fact is that this is a purely mathematical expression. When we are dealing with a simple two-dimensional surface, like that of the Earth, situated in our ordinary, familiar three-dimensional space, a certain mathematical function of our survey of the surface happens to represent our ordinary idea of its curvature, and for that reason the function is called the curvature. Now our imaginations will not extend to a three-dimensional "surface" situated in a four-dimensional continuum, but our mathematics can easily be generalized to include any number of dimensions, so that mathematically we can speak of the curvature of this three-dimensional "surface" which is our ordinary space. But it is a great mistake to try to picture this, for it is quite impossible. All we can imagine is the set of measurements we make and the relations between them, and it would be far better to speak of those imaginable things than to transfer a quite legitimate mathematical metaphor into a sphere of thought where it has no

place. Space is curved only in a mathematical sense; in terms of what we ordinarily mean by curvature, the idea is meaningless.

The present idea of the expanding universe thus owes its existence to the impact of observation on a set of possibilities offered by relativity mechanics. Theoretically, the static Einstein universe is possible, provided that space is finite, though unbounded. The expanding universe, however, is subject to less limitation. Either finite or infinite space is permissible if it is expanding, for there is then no imperative necessity for every ejected body to return to the system; it all depends on the conditions of the expansion. We may therefore have a finite amount of matter homogeneously distributed in a region in such a way that its parts are continually getting further and further apart; or we may have an infinite amount of matter similarly distributed. Which we actually have we do not know. Possibly we have neither, for the distribution of matter may not be homogeneous, and in that case, many other possibilities are open. With our present limited knowledge, however, we prefer to think that there is no unique region of space, such as the place of greatest density would be, and so far as observation has extended, our preference is justified. We must not forget, however, that all that we can yet observe may be not only a very small part of the whole, but a part which is not large enough to show anything but local peculiarities. A surveyor of a mountain range would hardly discover the true spheroidal form of the Earth by generalizing his observations. It therefore remains quite possible that the universe is static on the large scale, and that the expansion we observe is local—not in space alone, but also in time. In that case it may later cease and turn to a contraction—the whole universe, while showing these minute disturbances, remaining majestically quiescent on the grand scale.

There is a tendency to suppose that this cannot be because, as Eddington has shown, the static Einstein universe is unstable, and a small disturbance would necessarily make it expand or contract. This argument, however, seems to me to work in just the opposite direction. If we are actually considering the whole universe, then there is no difference between stability and instability. A mechanical system is stable when, if it is very slightly disturbed by some external force, it tends to recover its former state; and it is unstable when, in the same circumstances, it tends to depart further from its former state. Now what Eddington has shown is that if we have an Einstein universe, one such disturbance would necessarily destroy its static state and set it expanding or contracting, and he concludes that such

a disturbance occurred sometime in the past. But if he is actually dealing with the universe, such a disturbance cannot happen because there is, by hypothesis, nothing outside to cause it: if there is something outside (i.e., not outside a region of space but outside the content of the definition of the mechanical system), then the system is not the universe. Insofar, then, as relativity mechanics or astronomical observation indicates that the system of spiral nebulae has expanded through the disturbance of a primordial Einstein system, it indicates also that that system was not the universe but only a part thereof which was affected by the rest. It therefore argues in favor of the idea that our expanding system of nebulae is merely a local unit in a larger universe.

This is one of several examples of the difference between the mechanical problems of the universe and those of any partial system. The whole of physical nature has unique characteristics arising simply from the fact that it is the whole and not a part, and nothing is easier than to overlook this difference and apply "established" mechanical laws where properly they are inapplicable. Another example is the inapplicability of the ordinary process of *abstraction*. We can abstract laws of motion from moving planets, falling stones, rolling billiard balls, swinging pendulums, and so on, by ignoring everything that is not common to all such things, but we cannot ignore anything in the universe. There is only one universe, and therefore there is no difference between essential and accidental characteristics: they are all one. Again, all considerations of probability are irrelevant. It is quite illegitimate to seek the most probable behavior of a universe by considering many universes, as in statistical mechanics we seek the most probable behavior of an assembly of molecules by considering many such assemblies. Many universes are not merely actually non-existent; they are logically non-existent, for the universe is by definition the whole. This fact also has been conspicuously overlooked, I think, in certain considerations of the character of the universe. And, as a final example, the universe is the only mechanical system which has no boundaries, and therefore the problem of the universe differs from all other mechanical problems in having no boundary conditions.

For these reasons, I do not feel greatly concerned about the most prominent enigma in the present position of the universe problem—namely, the very short time-scale by which we appear to be faced. The recession of the nebulae can be extrapolated backwards to a time when all the matter forming them was more or less together in one place, and that time is no longer ago than about 2×10^9 years—which

is smaller than is convenient to explain certain characteristics of stellar astronomy. Certainly the problem is a very pertinent one, and deserving of all consideration, but it seems to me that whenever the requirements of the theory of the universe come into conflict with the requirements of special studies, it is the former that is far more likely to yield. The universe itself is a postulate—it is not something we observe: and the conditions of its study are so peculiar and so little apprehended as yet compared with those of partial problems that it seems fantastic to allow wide extrapolations from the most difficult of observations to dominate the detailed studies on which scientific laws themselves are founded. The study of the universe is helpful if it lifts our minds above the limitations imposed by undue specialization, but it becomes harmful if we allow it to fetter us still further in our consideration of the actual.

GEOPHYSICS.—*Some aspects of geophysical cycles.*[1] J. BARTELS, Department of Terrestrial Magnetism, Carnegie Institution of Washington. (Communicated by L. R. HAFSTAD.)

The common geophysical cycles of everyday experience can be connected with the rotation of the earth (solar and lunar diurnal-variations) or its revolution (annual variations), with the sun's rotation (27-day recurrence in terrestrial-magnetic activity, etc.), or with some physical resonance-effect depending on the form of the essential differential equation (water-waves, seiches, seismic waves, etc.). The familiar up and down in the records of many geophysical and other phenomena (atmospheric pressure, temperature, rainfall, tree-ring widths, business indices, mortality, etc.) has challenged many efforts to trace cycles of other periods than a day or a year. The outcome of this extensive search, made with analytical, graphical, optical, or mechanical procedures, is a bewildering variety of cycles claimed, but all are of a controversial nature. This curious result seems to be due to inadequate methods of research. A study of typical cases is proposed, leading to an outline of a statistical theory of geophysical and cosmical periodicities. Before the cyclic effect has been established in the series of observations by statistical methods, a physical explanation cannot be attempted.

The usual mathematical analysis gives at the same time too much

[1] The subject of this paper formed the basis of a more extended address under the above title by the author at the 1087th meeting of the Philosophical Society. Received January 10, 1936.

and too little. The theorem of Fourier series, or the recently developed theory of almost periodic functions, assert namely that every finite series of observations can be satisfactorily approximated by a sum of sine-waves of different periods and amplitudes, and even an infinite number of such sums can be found. This purely mathematical fact does not lend any significance to each individual sine-wave. A continuation of the sum of sine-waves into the future ceases in general to fit and is therefore of no use for forecasting (example: H. Kimura's[2] analysis of relative sunspot-numbers 1750–1911; the 29 sine-terms, continued, disagree with the observed numbers since 1912[3]). A notable exception is furnished by tidal theory, in which the periods of the essential sine-waves in ocean-tides are derived from the astronomical data on the movements of earth, moon, and sun; the amplitudes and phases of these sine-waves are computed by harmonic analysis of at least one year of tide-gage observations and then used for prediction. The same holds for tides of the solid earth (experiments of Michelson and Gale).[4] Such a complete representation of the data as sums of interfering sine-waves, with periods of submultiples of a *master-period*, is the aim of many workers on cycles, but it can be misleading (example: Seasonal change of amplitude in diurnal variation of atmospheric temperature at Berlin can be interpreted as spurious *sidereal-time variation*).

The problem of cycles is only part of a more general one, namely that of the morphology of geophysical time-curves, which should comprise an adequate mathematical description of the essential features of such curves. For simplicity, only values given at equidistant time-intervals (hourly values, etc.) are considered. Such a group of values for the same quantity, regarded as a statistical population, can be submitted to the ordinary procedures for computing averages, frequency-distributions, standard deviations, etc. These statistical conceptions are mostly developed in biometry. There is, however, a fundamental difference between lists of data in biometry and the time-series of geophysical observations; successive data in the former case are mostly independent (random), while geophysical data mostly show positive conservation, that is, high values are more likely to be followed by other high values, etc. Thus, for example, if one examines the differences of consecutive random numbers he finds in them negative conservation, whereas a similar examination of

[2] Mon. Not. R. Astr. Soc. 73: 543–548. 1913.
[3] Terr. Mag. 39: 231–236. 1934; 40: 215–217. 1935.
[4] Astroph. J. 50: 330–345. 1919.

daily sunspot-numbers will reveal positive conservation. The original ordinates may be y, and the averages of h successive ordinates may be $y(h)$; the standard deviations may be $m=m(l)$ for the y, and for the $y(h)$. For random-ordinates, $m(h)=m/\sqrt{h}$; for ordinates with conservation, this is measured by $\sigma(h)$ $[m(h)/\sqrt{h}]$.[2] Because $m(h)=m/\sqrt{h/\sigma(h)}$, $\sigma(h)$ is called *equivalent number of identical ordinates*, or $h/\sigma(h)$ is called *equivalent number of random-ordinates among* h *successive ordinates*. $[\sigma(2h)/\sigma(h)]-1$ is the ordinary correlation-coefficient between successive averages. Example: Daily relative sunspot-numbers, near sunspot-maximum; for $h=365$, $h/\sigma(h)$ is only 2.6. If $\sigma(h)$ approaches a limit σ, this might be called the *natural time-unit* for the quantity.

The usual computation of cycles is demonstrated for the lunar atmospheric tide. It begins with arranging the data in rows (individual sets) of r ordinates, and forming *average sets*, which consist of the averages of the r columns of h individual sets. The standard deviation of the individual sets may be ζ, that of the average sets may be $\zeta(h)$. In the *random-case*, in which there is no significant cycle of a period comprising r ordinates (these ordinates themselves may be random or not!), $\zeta(h)=\zeta/\sqrt{h}$; otherwise, $\sigma(h)$ can be computed as above as the square of the ratio $\zeta(h)$ to $\zeta/\sqrt{h}$, and, if significantly different from unity, denotes quasi-persistence (the analogue of conservation), measured by $\sigma(h)$, the *equivalent length of sequences*. If $\sigma(h)$ approaches a limiting value $\sigma(\infty)$, the series shows *asymptotic quasi-persistence* (example: Twenty-seven-day recurrences in terrestrial-magnetic activity, $\sigma(\infty)$ between 3 and 4). If $\sigma(h)$ is asymptotically proportional to $\sqrt{h}$, a *persistent wave* is found.

Harmonic analysis allows a refinement of this method by taking into account the conservation in the original ordinates. Individual sets of r ordinates, in the time-interval $t=0$ to 2π, are represented by sums of terms $(a_\nu\cos\nu t+b_\nu\sin\nu t)=c_\nu\sin(\nu t+\alpha_\nu)$. In the *harmonic dial* for fixed frequency ν, an individual wave is represented by a plane vector with the rectangular coordinates a_ν, b_ν, and the polar coordinates c_ν, α_ν, or only by the endpoint of this vector; in the *generalized harmonic dial* in $(r-1)$ dimensions, the vector has the coordinates a_1, b_1, a_2, b_2, . . . , and the square of its length is $c_1^2+c_2^2+\cdots=2\zeta^2$. For random-ordinates, the mean c_ν^2 is about $4\zeta^2/r$, independent of the frequency; in ordinates with conservation, the mean c_ν^2 is smaller than that value for higher frequencies, and greater for low frequencies. The mean c_ν plotted against ν gives the *mean periodogram*.

Cycles with fixed period can be classified by considering *clouds of points* in the (plane or generalized) dial. The dimensions of these clouds are given by the mean harmonic amplitude, c for individual sets, $c(h)$ for averages of h sets. For random-cycles, $c(h) = c/\sqrt{h}$, that is, the clouds for averages shrink in the ratio $1/\sqrt{h}$ with respect to the origin. In case of quasi-persistence, the clouds shrink more slowly than in the ratio $1/\sqrt{h}$, namely, in the ratio $1/\sqrt{h/\sigma(h)}$, with $[c(h)/(c/\sqrt{h})]^2 = \sigma(h)$. $\sigma(h) = \sigma(\infty)$ denotes asymptotic quasi-persistence. These conceptions may be illustrated nicely by examples dealing with terrestrial-magnetic activity; a number of such are treated by the author in his paper *Random fluctuations, persistence, and quasi-persistence in geophysical and cosmical phenomena*[5] where *random-walk* and *summation-dial* are used for illustration instead of shrinking clouds. A complete analysis should comprise the whole spectrum, but the actual amount of necessary calculations is reduced because of the *infective property* of quasi-persistence in cycles of adjacent periods.

Correlations between cycles in different phenomena are traced by *setting* the clouds in one dial to the same phase and turning the phases of coordinated vectors in the other dial by the same phase-angle. An example: Suicides in Berlin 1906 to 1914, compared with terrestrial-magnetic activity, full or half solar-rotations (27- or 13.5-day cycle); no appreciable correlation, contradicting the conclusions of T. and B. Düll.[6]

This statistical aspect of cycles is imposed by the fact that, instead of the carefully planned experiments in the laboratory, geophysics often provides us, so to say, with a number of large-scale experiments which all go on simultaneously, and the results of which have to be disentangled. The methods described need not be applied in detail in each case, because, after some experience, the examination of some samples will suffice for estimating the significance and the characteristics of a cycle. As to the mathematical side, the methods may be considered as a first attempt to amalgamate the ideas of A. Schuster[7] on the statistical aspect of hidden periodicities with those of Lexis[8] on super-normal and subnormal dispersion in ordinary statistical series; there is room for considerable refinement, because the formulae

[5] Terr. Mag. **40**: 1–60. 1935.
[6] Bioklim. Beibl. **2**: 24–31. 1935.
[7] Terr. Mag. **3**: 13–41. 1898; Cambridge Phil. Trans. **18**: 107–135. 1899; Phil. Trans. R. Soc., A, **206**: 69–100. 1906.
[8] H. L. Rietz, *Mathematical statistics*, 146–155 (1927).

were derived roughly as an emergency measure not only for detecting significant cycles, but even more for checking the exuberant production of cycles claimed without adequate tests, or, worse, after misleading applications of distorted *periodogram* tests.

PALEONTOLOGY.—*A new mustelid carnivore from the Neocene beds of northwestern Nebraska.*[1] C. LEWIS GAZIN, U. S. National Museum.

In the spring of 1935 the U. S. National Museum purchased from Mr. Ted Galusha of Hay Springs, Nebraska, a fossil mustelid skull from the later Tertiary of Nebraska. The specimen was found in a draw to the south of Antelope Valley, near the center of the southern half of Sec. 30, T. 31 N., R. 47 W., Dawes County, Nebraska. The deposits at this locality are believed to be equivalent to the Snake Creek beds, but the horizon represented in this series is not definitely known. The age is apparently upper Miocene or possibly lower Pliocene.

The skull is unique in comparison with living forms and is distinct from known skulls of fossil mustelids, and although comparisons with fossil forms known only from lower jaws are difficult, and perhaps unsatisfactory, an analysis of the requirements for dental occlusion apparently eliminates it from previously described genera.

Craterogale,[2] n. gen.

Type.—Craterogale simus.

Generic characters.—Skull short and broad; strong postorbital processes and rugged, separate temporal ridges; prominent lambdoidal crests and mastoid processes; zygomae deep, powerful, and widely expanded; infraorbital foramen of moderate size and nearly circular; basicranial region short with large bullae firmly fused to surrounding elements; bullae project markedly downward, forward, and slightly inward, with antero-externally directed foramen through projected portion; audital tube short; foramen ovale, foramen lacerum medius, and eustachian foramen closely grouped; dental formula $\frac{?-1-2-1}{}$; teeth small and stout; P^3 relatively small; P^4 with small parastyle, deuterocone well forward, and without tetartocone; M^1 with elongate external portion, conspicuous parastyle, and moderately large heel which is expanded anteroposteriorly to about the same extent as the external portion; protocone of M^1 large and hypocone less prominent.

[1] Published by permission of the Secretary of the Smithsonian Institution. Received February 17, 1936.

[2] Derived from the Greek *krateros*, strong, *gale*, weasel.

Craterogale simus,[3] **n. sp.**

Type.—Nearly complete skull, U.S.N.M. no. 13801, including P^3 to M^1 on both sides.

Horizon and locality.—Snake Creek (?) beds, Upper Miocene or Lower Pliocene, Dawes County, Nebraska.

Specific characters.—Only known species; size of skull approximately one-fifth larger than that of *Mephitis nigra*, but much more rugged; P^2 to M^1 about 24 mm. Other specific characteristics are not clearly discernible in the absence of additional species.

Description of skull.—The skull of *Craterogale simus* is intermediate in size between that of a fisher, *Martes pennanti*, and of a martin, *Martes americana*, but relatively much broader and more rugged than either. The skull is proportioned somewhat more as in *Mephitis*, though larger, and with a breadth suggestion of the felids.

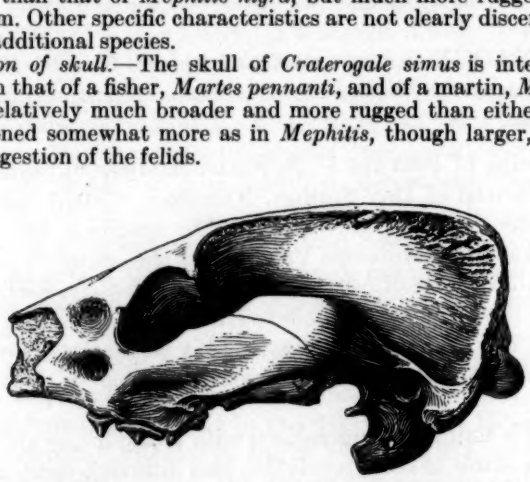

Fig. 1.—*Craterogale simus*, n. gen. and sp. Skull, type specimen, U.S.N.M. no. 13801, lateral view, natural size. Upper Miocene or lower Pliocene, Dawes County, Nebraska. Drawing by Sydney Prentice.

The rostrum is short and broad with prominent pre-orbital or lachrymal fossae. The orbital cavities, though open posteriorly, are well defined by prominent postorbital processes of the frontals and noticeable, but less developed, processes on the jugals. The anterior margin of the orbit is interrupted by a marked outward and upward projection of the lachrymal bone. Laterally the maxillae join deep and powerful zygomae. The relative development of the zygomatic arch is not approached in any of the living mustelids and its depth is actually equal to or greater than that in much larger individuals of the wolverine. On its anterior and ventral surface the zygoma shows a marked excavation, presumably for attachment of the anterior masseter lateralis. The infraorbital foramen is of moderate size, nearly circular, and terminates anteriorly above P^3. On the dorsal surface of the rostrum the premaxillae project backward between the nasals and maxillae to a point of contact with the frontals. In some mustelids, as in the Mephitinae the premaxillae apparently do not extend so far back, but in the Lutrinae, for example, both conditions are found.

The cranial portion of the skull is moderately elongate and not greatly inflated, much less so than in *Lutra* or *Taxidea*. The dorsal surface of the cranium is characterized by strong, outstanding temporal ridges, more

[3] Derived from the Greek *simos*, snub-nosed.

rugged than in *Helictis*, extending from the prominent postorbital processes and remaining separate to the occipital crest. The ridges most closely approach one another at a point slightly posterior to the postorbital constriction and are most outstanding near the occipital crest. A weak sagittal crest is present from about the postorbital constriction to the occiput.

The posterior or occipital portion of the skull exhibits heavy lambdoidal crests which extend from the temporal ridges at the top of the occiput in diverging, nearly straight lines to the prominent mastoid processes. These ridges project outward and backward to a marked degree. The paroccipital processes, just posterior and median to the mastoid processes, are not completely preserved but do not appear to have been developed so strongly as the mastoid processes. The surface of the occiput shows a moderately inflated median ridge from the foramen magnum below to the crest of the occiput. The foramen magnum and the occipital condyles are of moderate size and the surface of articulation extends entirely around the lower margin of the foramen.

The palate is broad and short, though relatively a little longer than in *Mephitis*, and shows a prominent groove on each side extending forward from the principal posterior palatine foramina. These foramina are located inward from about the middle of the carnassials, not so far forward as in the otters and skunks, nor so posteriorly placed as in the badgers. The portion of the palate extended posterior to the dentition is noticeably concave transversely and projects backward to a point about equivalent to that in *Lutra* or *Helictis*, more than in *Mephitis*, and distinctly less than in many forms such as *Tayra*, *Grisonella*, *Taxidea*, *Meles*, and the fisher, *Martes pennanti*. The width of the posterior narial opening is about as in *Mephitis* or *Conepatus*, but with no indication of the partition conspicuous in the mephitines. Between the molar tooth and the posterior narial opening, on each side of the extended portion of the palate, is a small though conspicuous process, apparently defining the antero-ventral limit of the origin or attachment of the pterygoid muscles. A similar process is present on the external surface of the pterygoid plate, on the antero-dorsal margin of the pterygoid fossa opposite the hammular process. These appear well defined in comparison with living mustelids.

Perhaps the most striking character of the skull is the extent to which the bullae project below the basis cranii. The bulla appears well inflated, relatively perhaps as much as in *Taxidea*, with a more transversely compressed portion extending downward, forward and slightly inward. Just below the inflated portion the tympanic exhibits a large foramen directed outward and forward from the medial surface. The osseous portions extending downward behind and in front of this aperture are tightly closed below but not coossified. Apparently this remarkable development on the tympanic is due to a muscular attachment along the ventral margin, possible extending back nearly or entirely to the base of the paroccipital process. In all probability this muscle was the digastricus. Such a marked development at its origin would be entirely in keeping with the unusual development indicated for the masseter and temporalis. The digastricus usually originates at the paroccipital process, but according to Windle and Parsons[4] in terrestrial carnivora it also arises "often from the contiguous paramastoid and bulla tympani." Reighard and Jennings[5] note that in the cat the digastricus originates

[4] WINDLE, B. C. A., and PARSONS, F. G. Proc. Zool. Soc. London, pp. 376–377. 1897.

[5] REIGHARD J., and JENNINGS, H. S. *Anatomy of the Cat*, p. 107, New York, 1929.

"from the outer surface of the jugular (paroccipital) process of the occipital bone, and by tendon from the tip of the mastoid process and from the ridge between the mastoid and jugular processes." This latitude for attachment in carnivora leads one to suppose that in this instance the origin of the digastricus extended well forward on the bulla. Other muscles originating in this region, with forward insertions, such as the styloglossus and stylohyoid, are not eliminated but it seems unlikely that these would be developed to the extent indicated by the process on the bulla.

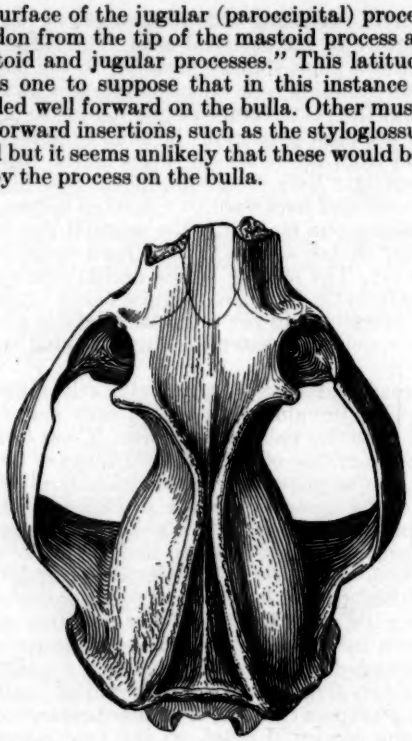

Fig. 2.—*Craterogale simus*, n. gen. and sp. Skull, type specimen, U.S.N.M. no. 13801, dorsal view, natural size. Upper Miocene or lower Pliocene, Dawes County, Nebraska. Drawing by Sydney Prentice.

The foramen enclosed by the ventral projection from the tympanic is relatively large. Its direction and position suggest that it may have carried the external carotid artery. After leaving the side of the trachea this artery turns outward, gives off various branches including the internal carotid and occipital arteries, passes deep to the digastricus and between the digastricus and styloglossus. Assuming that the muscle which has its origin on the bulla was the digastricus, the external carotid in maintaining its normal relations would have either passed through the foramen or anterior to the bulla and thence external to the styloglossus and the bones of the hyoid. If the styloglossus muscle in part originated at or near the mastoid process and the stylohyoid bone was attached in a normal position near the stylomastoid foramen then the external carotid in passing through the foramen in question would be in a position to meet these conditions with the least deviation from its normal course. The inferred course of the external carotid through the foramen which is approximately in its normal path seems likely inasmuch as the position of the artery would have been established in the tissue before ossification had surrounded the vessel. If it could be

demonstrated that the carotid ascended external to the bulla then the foramen might have been occupied by the posteriorly directed internal carotid and occipital arteries.

The jugular veins are apparently eliminated as possibilities since the internal jugular passes posteriorly from the foramen lacerum posterius and the external jugular descends superficial to the position in question. Of the nerves which pass forward from the vicinity of the foramen lacerum posterius only the ninth and twelfth, the glossopharyngeal and hypoglossal, are not entirely eliminated, but these would apparently descend to the vicinity of the pharynx and then forward to the tongue, and not outward enough to have gone through the foramen in the projected portion of the bulla.

The bullae in *Craterogale simus* are of additional interest in being so completely fused with the adjacent bone elements, apparently a strengthening associated with the muscular attachment to the bullae. Medially the bullae join the basioccipital and basisphenoid forming a nearly smooth, transversely concave surface. Postero-externally and posteriorly the prominent mastoid process and incomplete paroccipital process are separated from the bulla by an acute notch, but at the roots of these processes the mastoid and exoccipital bones are firmly joined to the bulla. Anteriorly and antero-externally the bulla is strongly united to the alisphenoid and squamosal. The anterior margin of the bulla is not curved backward dorsally to meet the alisphenoid and squamosal, and does not exhibit a transverse fissure as observed in forms having inflated bullae, such as *Taxidea*, *Gulo*, and *Martes*, but is extended forward, lapping out on the postero-ventral surface of the postglenoid almost or quite to its anterior margin (a condition noted by Matthew[6] in *Leptarctus*).

The external audital tube is short due to the inflation of the bulla, and is solidly joined to the adjacent squamosal and periotic bones, quite filling the space between the zygomatic and mastoid processes. The meatus is moderately large, nearly circular and directed outward about perpendicular to the median vertical plane of the skull, not forward as in so many of the mustelids.

The glenoid surface is well developed, with a relatively broad postglenoid process as in *Mephitis* and with the anterior margin of the fossa extended forward uniformly about as in *Martes*. The outer portion of the anterior margin is prominent but does not recurve to form a locking joint as in *Lutra* and *Gulo*.

As general in mustelids the alisphenoid canal is absent, unless its openings are entirely concealed in the recesses of the foramen rotundum and foramen ovale, which seems unlikely. The opening of the optic foramen occupies a position farther forward from the foramen lacerum anterius than in *Mephitis* but relatively not so far forward as in *Martes*. The foramen lacerum anterius and foramen rotundum are separate but placed very close together. Posterior to these and at the antero-median margin of the bulla the foramen ovale, eustachian foramen, and foramen lacerum medius are very closely grouped together. The foramen ovale opens unusually close to the eustachian foramen, closer than in *Mephitis*, and is separated from this opening and the foramen lacerum medius by a thin plate of bone which extends forward as a ridge to form the posterior margin of the pterygoid plate. The small posterior opening of the carotid canal is forward of the foramen lacerum posterius about one third of the distance to the foramen lacerum medius. Be-

[6] MATTHEW, W. D. Bull. Amer. Mus. Nat. Hist., 50: 138–146. 1924.

cause of the obliterated contact between the bulla and the basioccipital and basisphenoid the elements forming the canal cannot be certainly determined but the position of the canal opening on the bulla suggests that it was probably entirely within the bulla. The small condylar or hypoglossal foramen is situated close to the postero-median margin of the large foramen lacerum posterius. In this respect its position is similar to that in *Martes* and some of the other genera of mustelids. In specimens of *Mephitis* examined the condylar foramen is much closer to the condyles. The stylomastoid foramen is partially obscured in the deep cleft between the bulla and the ridge connecting the paroccipital and mastoid processes. In the case of the postglenoid foramen a somewhat anomalous condition exists in which the postglenoid or temporal canal opens in two positions on both sides. In one position the opening is approximately as in *Lutra*, *Taxidea*, and *Gula*, antero-ventral to

Fig. 3.—*Craterogale simus*, n. gen. and sp. Skull, type specimen, U.S.N.M. no. 13801, ventral view, natural size. Upper Miocene or lower Pliocene, Dawes County, Nebraska. Drawing by Sydney Prentice.

the audital tube, but is very close to the postglenoid process. In the second position, antero-dorsal to the audital tube and along the posterior wall of the zygomatic process of the squamosal, the opening is similar to that in *Mephitis*. The two openings though widely separate at the surface presumably join beneath the included segment of the audital tube which has fused to the squamosal. A similar condition was observed in a recent skull of *Taxidea taxus*.

Description of teeth.—The type of *Craterogale simus* exhibits the 3rd and 4th upper premolars and the 1st molar on both sides, and alveoli for the canine and 2nd premolar. In all probability the completed formula was as follows: $I\frac{3}{3}$, $C\frac{1}{1}$, $P\frac{3}{3}$, $M\frac{1}{1}$. The combination of cheek teeth is common among mustelids, occurring typically in such genera as *Mustela*, *Mephitis*, *Spilogale*, and *Taxidea*.

The teeth, though sturdy, are small considering the muscular development indicated for the lower jaw. P^2, as shown by the alveoli, was two rooted, with the anterior root small and placed inward from the canine alveolus. P^3 is simple, without accessory cusps or styles, and exhibits a slight cingulum around the medial and posterior margin of the tooth. This tooth is separated by a short diastema from the posterior alveolus of P^2.

The carnassial is moderately low crowned and in occlusal view is nearly triangular in outline. The shearing blade is relatively broad transversely, and blunt, although the bluntness may be largely due to wear. The deuterocone (or protocone) is a distinct conical cusp placed well forward at the antero-lingual angle of the tooth, much as in *Martes* and *Mustela*, farther forward than in *Mephitis*. The lingual margin of the tooth posterior to the deuterocone is almost a straight line, with no appreciable indentation to set off the deuterocone such as observed in *Martes*. This inner portion of the tooth is without talon or tetartocone, but exhibits a weak cingulum for a short distance posterior to the deuterocone. The anterior margin of the tooth, extending from the deuterocone to a weak parastyle at the antero-external angle of the tooth, is only slightly indented, much less so than in *Martes* or *Mustela*. On this portion of the tooth margin the cingulum is conspicuous, and continues around on the outer surface, becoming weaker posteriorly.

The molar tooth is relatively large, with the outer portion distinctly long anteroposteriorly and the summits of the paracone and metacone well spaced. The portion of the tooth extending outward from the ridge connecting the paracone and metacone projects prominently forward and outward from the paracone, forming a conspicuous style at the antero-buccal angle of the tooth. The lingual portion of the tooth is well developed, but the heel is not so markedly expanded as in *Lutra*, *Taxidea*, or *Conepatus*, though almost as much as in *Mephitis*. The fossil molar, however, does not show the median anteroposterior constriction seen in *Mephitis* and many other mustelids. The protocone is prominent and rather centrally placed as compared with *Mephitis* and *Lutra*. It may be noted that the antero-ventral surface of the ridge connecting the protocone to the paracone is considerably worn. The hypocone is moderately developed but is not expanded so prominently as in *Mephitis* and *Lutra*. A moderate cingulum extends forward from the hypocone, around the antero-lingual side of the protocone, but its development is not comparable to that in *Martes* and *Mustela*. The ridge extending buccally from the posterior extremity of the hypocone is also noticeably worn, presumably through occlusion with M_2.

Comparisons with fossil forms.—Of the comparisons which may be made with other fossil mustelids, that with *Leptarctus* is among the most pertinent. *Craterogale simus* shows a striking resemblance in skull structure to *Leptarctus primus*, as illustrated by Matthew,[7] but exhibits a distinctly different type of dentition. Points of similarity between the two are seen in the short and broad skull, deep and widely expanded zygomae, prominent postorbital processes, separate and rugged temporal ridges, heavy lambdoidal crests, short basicranial region with large bullae which are markedly fused with the postglenoid processes, very short audital tube, and in the absence of P^1 and M^2. No detailed comparisons with the bullae can be made since these elements are incomplete in the *Leptarctus* skull. *Craterogale simus* differs from *Leptarctus primus* in a narrower postorbital constriction, less widely sepa-

[7] MATTHEW, W. D. Bull. Amer. Mus. Nat. Hist., 50: 138–146, fig. 37, 1924.

rated temporal ridges (perhaps a matter of age), a less convex profile anteroposteriorly along the temporal ridges and dorsoventrally along the lambdoidal crests, P^4 without tetartocone (hypocone), and M^1 shorter and relatively wider transversely. The dental structure in *Craterogale* is more nearly that of a typical mustelid, whereas that in *Leptarctus* makes a closer approach to certain of the Melinae.

Among the other mustelids known from the Snake Creek beds, *Mionictis* makes the nearest approach to the type of lower dentition presumed for *Craterogale*, and comparisons between the two forms are not entirely satisfactory. The species of *Mionictis* are of relatively small size, though actually larger than *Craterogale simus*. The premolars are three in number and do not have accessory cuspules, but the premolar series is relatively longer and the premolars relatively larger and more elongate than would be expected in *C. simus*. The lower carnassial in species of *Mionictis* has a large talonid, as seems evident for *C. simus*, but the length of this tooth in the smallest of the two forms, *Mionictis elegans*, is 11 mm. The length of this tooth in *C. simus* apparently could not have been greater than about 9 1/2 mm and was probably about 8 1/2 mm.

Plionictis is one of the better known upper Miocene mustelids, having as its type *P. ogygia*[8] which is represented by both skull and mandible. The skull of *Craterogale simus* is quite unlike that of *Plionictis ogygia* in the development of the zygomae, and in having rugged temporal ridges. Moreover, the upper molar in the *Plionictis* skull is much shortened anteroposteriorly. This and other characters in both upper and lower dentitions of *Plionictis* are modifications in the direction of *Mustela*.

Craterogale is distinct from *Brachypsalis* in having a more reduced dentition. The maxillary portions referred by Matthew to species of *Brachypsalis* show alveoli for a second molar, and the upper carnassials and molars in these specimens belong to much larger species than *C. simus*. The upper carnassials in the species referred to *Brachypsalis* are illustrated[9] as having more medially extended deuterocones, and the first upper molars show a less prominent antero-buccal angle, a stronger hypocone, and a more outstanding cingulum antero-medial to the protocone.

The species of *Sthenictis* are characterized by a less reduced lower premolar series as are species of *Martes*, unlike the shortened type of jaw which is evident for *Craterogale*. The lower carnassial in *Sthenictis bellus* and *S. dolichops* from the Sheep Creek and lower Snake Creek horizons respectively, and in the similar *Cernictis hesperus*[10] from the Pliocene of California, has a relatively smaller talonid than is indicated for *Craterogale*.

Plesictis[11] from the Oligocene of Europe exhibits marked temporal ridges, and the upper carnassial, though relatively longer, resembles that in *Craterogale*. However, the skull of *Plesictis* is more elongate, has weaker zygomae, four instead of three premolars, and the bullae, though inflated, do not project ventrally as in *Craterogale*. M^1 in *Plesictis genettoides* is relatively short and transversely wider, with a somewhat less expanded heel than in *Craterogale*.

Remarks.—The relationships of *Craterogale simus* are obscure, due largely

[8] MATTHEW, W. D. Mem. Amer. Mus. Nat. Hist. 1 (7): 383–384, figs. 8–9, 1901.
[9] MATTHEW, W. D. Ibid., pp. 131–134, figs. 29–33, 1924.
[10] HALL, E. R. Jour. Mammalogy 16: 137–138. 1935.
[11] See H. HELBING, Abh. schweiz. palaeont. gesells. 50: 1–21, pls. 1–4, 1930; and J. VIRET, Ann. Univ. Lyon, n. s. fasc. 47: 166–183, pl. 15: pl. 16, figs. 1–2; pl. 30, figs. 1–4, 1929.

to the incomplete nature of so much of the fossil mustelid material which has been described from North America. It is possible that *Craterogale* is related to *Mionictis*, but this can not be demonstrated from the known material. On the other hand the structural similarity between this skull and that of *Leptarctus* as far as known seems more than mere coincidence, although the teeth are very distinct. However, the differences between the dentitions may not be much greater than between some mustelid genera which have been referred to the same subfamily, such as between *Meles*, *Helictus*, *Arctonyx*, and *Taxidea*, or as between *Lutra*, *Latax*, and *Enhydriodon*.

The skull characters exhibited by *Craterogale*, which possesses a truly mustelid dentition, furnish additional evidence for mustelid affinities of *Leptarctus*. Moreover, the cranial characters of *Leptarctus*, as described and figured by Matthew, seem to warrant recognition of a separate subfamily, the Leptarctinae, to which *Craterogale simus* may be referred tentatively.

MEASUREMENTS (IN MILLIMETERS) OF SKULL OF CRATEROGALE SIMUS

Length from anterior margin of nasals to occipital condyles	79.2
Length of nasals	17.3
Distance from anterior margin of nasals to line between postorbital processes of frontals	27.3
Distance from postorbital processes to posterior margins of lambdoidal crests	49.6
Width between orbits	21.8
Width at postorbital constriction	15.5
Width across zygomatic arches	61.0
Greatest depth of zygomatic arch	13.8
Width across mastoid processes	41.2
Width across occipital condyles	19.4
Depth from temporal crests to ventral extremities of bullae	41.3
Distance from posterior margin of palate to foramen magnum	38.0
Width of palate between molars	14.3
Length of cheek tooth series, P^2–M^1	24[a]
P^2, anteroposterior diameter	5.0
P^2, transverse diameter	3.0
P^4, anteroposterior diameter parallel to outer wall	7.7
P^4, greatest length over deuterocone	8.7
P^4, transverse diameter perpendicular to outer wall	5.6
M^1, anteroposterior diameter perpendicular to anterior margin	5.8
M^1, greatest diameter	9.6
M^1, transverse diameter perpendicular to outer margin	7.2

[a] Approximate

BOTANY.—*Three new grasses from Mexico and Chile.*[1] JASON R. SWALLEN, Bureau of Plant Industry.

Among the grasses in a recent collection of plants made by Francis W. Pennell in Mexico, were two new species of *Muhlenbergia*. One of these was found in the Sierra Gazachic, 35 kms. southwest of Minaca, Chihuahua, and the other in the Sierra Madre Occidental, near El Salto, Durango. The third species here described was collected at Cajon de los Pelambres, Dept. Illapel, Chile, by G. Looser.

[1] Received February 14, 1936.

Muhlenbergia lucida Swallen, sp. nov.

Perennis; culmi caespitosi, erecti, 60 cm alti, pubescentes; vaginae puberulae vel scaberulae, internodiis longiores; ligula obtusa, 3–6 mm longa; laminae 15–30 cm longae (superiores 2–5 cm longae), involutae, flexuosae, puberulae vel scaberulae; panicula 15 cm longa, ramis filiformibus, flexuosis, implicatis, basi nudis; pedicelli 10–15 mm longi, filiformes, flexuosi; glumae 3 mm longae, obtusae, hyalinae, pilosae; lemma dense villosum, 4 mm longum, bifidum; arista 12 mm longa, obscure geniculata, basi tortilis; palea villosa lemma aequans.

Perennial; culms caespitose, erect, 60 cm tall, appressed-pubescent; sheaths longer than the internodes, minutely scabrous or appressed-pubescent, sometimes nearly glabrous; ligule firm, obtuse, 3 to 6 mm long; blades 15 to 30 cm long (the uppermost 2 to 5 cm long extending beyond the base of the panicle), flexuous, firm, involute, minutely pubescent or scabrous; panicle 15 cm long, the branches scabrous or pubescent, filiform, flexuous, implicate, naked at the base, the lowermost 5 to 6 cm long; spikelets distant, the pedicels filiform, flexuous mostly 10 to 15 mm long, gradually enlarged upward toward the summit; glumes equal, 3 mm long, obtuse, hyaline, pilose, nerveless; lemma densely villous, 4 mm long, bifid, the teeth 1 mm long, subacute, the midnerve prominent, red, extending from between the teeth into an awn 12 mm long, more or less geniculate, twisted below the bend; palea equal to the lemma, hyaline, villous.

Type in the U. S. National Herbarium no. 1614380 collected on ledges of igneous rock, "Barranca Colorad," Sierra Gazachic, alt. 2300–2500 m, 35 km. southwest of Minaca, Chihuahua, Mexico, September 16–17, 1934, by Francis W. Pennell (no. 18955).

Muhlenbergia lucida is probably most closely related to *M. argentea* Vasey, the only other perennial species which has bilobed lemmas. There are several well marked differences, however, which easily distinguish the latter, the most conspicuous being the narrow panicles with appressed or ascending branches, the short pedicled, appressed spikelets, and the nearly glabrous lemmas.

Muhlenbergia subaristata Swallen, sp. nov.

Perennis; culmi dense caespitosi, erecti, 120 cm alti, glabri vel minute pubescentes; vaginae internodiis longiores, scabrae; ligula truncata, 1–2 mm longa; laminae 15–30 cm longae, 1–3 mm latae, involutae vel planae, attenuatae, flexuosae, scabrae; panicula 25 cm longa, ramis adscendentibus basi nudis, usque ad 10 cm longis; pedicelli filiformes, flexuosi, 1–5 mm longi; glumae 1–1.3 mm longae, obovatae, obtusae, erosae, scabrae vel pubescentes; lemma 4–4.5 mm longum, scabrum vel pubescens, muticum vel arista usque ad 2 mm longa praeditum; palea acuta, lemmate paulo longior, scabra vel pubescens.

Perrenial; culms caespitose, erect, 120 cm tall, glabrous or minutely pubescent; sheaths rounded on the back, overlapping, or rarely a little shorter than the internodes, scabrous; ligule truncate, 1–2 mm long; blades loosely involute, becoming flat with age, flexuous, 15–30 cm long, 1–3 mm wide, attenuate to a fine point, scabrous; panicle narrowly pyramidal, 25 cm long, the compound branches, rather distant, ascending, naked at the base, the lowermost 10 cm long; pedicels filiform, flexuous, 1–5 mm long, densely

pubescent below the spikelets; glumes 1–1.3 mm long, obovate, obtuse, erose, scabrous, pubescent at the tip; lemma 4–4.5 mm long, purple, scabrous or pubescent, awnless or with an awn as much as 2 mm long; palea acute, equaling or slightly exceeding the lemma, scabrous or pubescent.

Type in the U. S. National Herbarium no. 18572 collected along river, above Arroyo de Agua, El Salto, Sierra Madre Occidental, alt. 2600–2650 m, Durango, Mexico, September 1, 1934, by Francis W. Pennell (no. 18572).

This species of *Muhlenbergia* belongs in the group with *M. capillaris* (Lam.) Trin., *M. rigida* (H.B.K.) Kunth, and *M. reverchoni* Vasey & Scribn., but differs from all in the short, usually obovate glumes, and from the first two in the awnless or short awned lemmas

Festuca panda Swallen, sp. nov.

Perennis; culmi dense caespitosi, 15–40 cm alti, nodo unico geniculati, glabri; folia basi aggregata; vaginae rubrae, glabrae, membranaceae; ligula ciliata 0.3–0.5 mm longa; laminae foliorum basalium firma, arcuatae, 2–5 cm longae, infra glabrae supra scabrae; lamina folii culmi 1 cm longa appressa; panicula 3–7 cm longa, ramis brevibus simplicibus appressis vel adscendentibus 1–3-spiculis; spiculae 8–10 mm longae, 4–5 florae, appressae; gluma prima acuta 1-nervia, 2.5–3 mm longa, glabra vel marginibus scaberula; gluma secunda obtusa, 3-nervia, glabra, marginibus scabris; lemma 6 mm longum, acutum, muticum, glabrum, marginibus scabris; palea acuta, lemma aequans, carinis scabris.

Perennial; culms densely caespitose, 15–40 cm tall, somewhat flexuous, usually geniculate at the single node, glabrous; innovations numerous; leaves crowded in a dense basal clump; sheaths reddish, glabrous, becoming membranaceous; ligule short-ciliate 0.2–0.5 mm long; basal blades distichous, firm, stiffly arcuate spreading, 2–5 cm long, glabrous on the lower surface, scabrous on the strongly nerved upper surface; culm blades one, 1 cm long, appressed; panicles 3–7 cm long, the short, simple branches appressed or ascending, bearing 1–3 spikelets; spikelets 8–10 mm long, 4–5 flowered, appressed; first glume acute, 1-nerved, 2.5–3 mm long, glabrous, or sparsely scabrous on the margins, the second obtuse, 3-nerved, glabrous, scabrous toward the tip and on the margins; lemmas 6 mm long, acute, awnless, scabrous on the tip and margins, otherwise glabrous or nearly so; palea acute, about equaling the lemma, scabrous on the keels.

Type in the U. S. National Herbarium, no. 1614378 collected at Cajon de los Pelambres, alt. 2900 m, Dept. Illapel, Chile, January 1932, by G. Looser (no. 2151).

The geniculate single noded culms with one short appressed culm blade are characteristic.

BOTANY.—Gilmania, *a new name for* Phyllogonum, *a very rare genus of plants from Death Valley, California, apparently in process of extinction.*[1]

FREDERICK V. COVILLE, Bureau of Plant Industry.

My attention has been called by Mr. C. V. Morton to the existence of a genus of mosses named *Phyllogonium*, older than the very rare

[1] Received March 14, 1936.

genus of flowering plants from Death Valley, California, named by me in 1893 *Phyllogonum*. Since the latter name therefore is not valid, I propose in place of it a new genus name, as follows:

Gilmania

Phyllogonum Coville, Contr. U. S. Nat. Herb. **4**: 190. *pl. 21.* 1893. Not *Phyllogonium* Brid. Bryol. Univ. **2**: 671. 1827.

The genus is now renamed in honor of Mr. M. French Gilman, of Banning, California, ornithologist and botanist, who has devoted years of observation and study to the flora of Death Valley and whose intelligent and persistent search for this seemingly lost plant has resulted in its rediscovery.

The original description of the genus is reprinted as follows:

Polygonacearum genus Eriogoneis affine. Nodi foliis tribus herbaceis petiolatis instructi. Flores lutei, pedicellati, ad nodos fasciculati, sine involucro sine bractea, facie in axilla folii, inserti, fasciculis superis brevitate internodorum adjacentibus, demum confluentibus.—Planta annua, prostrata, divergente ramosa, omnino luteola, ramis e nodo singulo tribus aut quinque, inaequalibus.

Nomen genericum e φύλλαν et γόνυ derivatum est, nodi enim folia tria plene expansa, nec ut plerumque in generibus propinquis bracteis reducta, gerunt.

The genus has but one species, which is given a binomial name as follows:

Gilmania luteola

Phyllogonum luteolum Coville, Contr. U. S. Nat. Herb. **4**: 190. *pl. 21.* 1893.

For an illustration and detailed description of the species and a discussion of the relationship of the genus to other genera of the family Polygonaceae, botanists are referred to the original publication.

The collections now available show that the plant when fully developed sometimes attains a diameter of more than 10 inches, the irregular rosette of stems lying flat on the ground. This habit and the yellow color of the stems and of the innumerable small flowers have suggested the common name goldcarpet. Even the leaves are yellowish. The specimens collected by Mr. Gilman show that when the plant reaches the fruiting stage the stems stand up from the ground, a position which undoubtedly facilitates the dispersal of the seeds.

The recorded history of *Gilmania* is as follows: On April 7, 1891, I found two specimens of an unknown plant in the lower part of Furnace Creek Canyon, Death Valley, California. They were growing in the dry gravelly wash of the canyon. No other specimens were seen. In the Botany of the Death Valley Expedition, published in 1893, these two specimens were made the basis of a new genus and species, *Phyllogonum luteolum*.

On May 18, 1915, Mr. S. B. Parish collected a few specimens of the plant

in Death Valley and in 1918, in *Notes on Some Southern California Plants*,[2] he said:

Very sparingly scattered among the pebbles covering the dry bed of the stream [Furnace Creek], immediately above the small marsh [Furnace Creek Springs] from which the stream rises, probably the exact spot where Coville, on April 7, 1891, collected the two specimens on which he founded the genus, since which time the plant has not been rediscovered. Two small specimens were also seen in a dry wash between Furnace Creek and Saratoga Springs. So far as known, the species is an endemic of Death Valley, and very rare even there. The plants are prostrate, and the largest found [by Mr. Parish] had stems hardly 3 cm long.

In his book, *Death Valley*, published in 1930, W. A. Chalfant, on page 85, gives the following statement by Professor Willis L. Jepson, who collected plants in Death Valley in 1917:

When on a long tramp down the Furnace Creek wash, my first trip down it, watching eagerly for the rare plants of the region, I saw a single individual of *Phyllogonum luteolum* about two inches high, a species known only from Death Valley. I took it and put it in my press, expecting to find enough of it, and went on down the wash. Within perhaps two hundred or two hundred and fifty yards I suddenly woke up to the fact that I was not finding any more, and so returned to the original spot, locating it with much difficulty. Whereupon I set up my plant press as a marker and carefully cast around the spot at an ever increasing distance for nearly an hour in the hope of finding other individuals, but failed. Nor did I on subsequent days find any more either there or elsewhere.

When I was again in Death Valley at the season for this evanescent annual, in April, 1931, and in April, 1932, accompanied on both journeys by Mr. M. French Gilman, we both searched very carefully for this plant, but found no trace of it, nor had Mr. Gilman been able to find it on previous journeys. He developed the theory that the few individual plants of this genus that had been collected in Furnace Creek wash had grown from occasional seeds that had been brought down the wash from some higher elevation which was the real home of the plant.

Mr. Gilman was again in Death Valley in 1934 and 1935. In 1934 he looked carefully for the plant but did not find it. In 1935 he renewed his search, and was rewarded by getting it in four different places, all within a few miles of the original locality.

The first plant of *Gilmania* found by Mr. Gilman, on April 14, 1935, was from the floor of Death Valley close to the foot of the mountains, two miles south of Furnace Creek Inn, a few rods south of the entrance to Golden Canyon, and about 100 feet below sea level. There were fourteen individual plants within a radius of 150 feet. Mr. Gilman afterward watched them carefully, but only three became large enough to flower and produce seed. The others dried up and died when they still had only a few leaves and no branches.

[2] Bot. Gaz. 65: 336. 1918.

The next locality found by Mr. Gilman, on April 20, 1935, was near Artists Drive, a road in the mountains, entered from the bottom of the valley at a point about six miles south of Furnace Creek Inn. Most of the plants were at an elevation estimated at a little over 1,000 feet, along the crests and slopes of a "whitish hill formation" which "seemed rather highly chemical." Farther down Artists Drive, in a larger canyon leading out to the floor of the valley, Mr. Gilman found three well-developed plants at the edge of a sandy wash at about 400 feet elevation. Altogether, about forty plants were seen in the two localities along Artists Drive. Most of them were very small, and later died from lack of rain.

On April 27, 1935, Mr. Gilman, starting from Teck Springs, about half a mile northeast of Furnace Creek Springs, went north of east into some "low yellowish-white hills" and found there about thirty-five plants of *Gilmania*, five or six of them of mature size, the others very small. They were scattered over several of the small hills at an altitude of about 1,000 to 1,200 feet. Part of the drainage of this area goes into Furnace Creek, and these hills may well have been the source of the plants that have been found heretofore in the dry gravel of that stream bed by Parish, Jepson, and myself.

Samples of the soil in which Gilmania plants were growing, obtained by Mr. Gilman, were examined at the Rubidoux Laboratory, Riverside, California, through the courtesy of Mr. C. S. Scofield. Mr. Scofield has reported on these soils as follows:

The three soil samples were tested for total soluble salts by digesting for 24 hours, with shaking, in water, at the ratio of 1 part of soil to 5 parts of water. The solutions thus obtained were analyzed. Sample No. 1, taken near the mouth of Golden Canyon, contained 0.816 per cent of total salts, chiefly calcium sulphate. Sample No. 2, from a yellowish-white ridge on Artists Drive, contained 1.042 per cent of total salts, also chiefly calcium sulphate. Sample No. 3, from the edge of a sandy wash on Artists Drive, at the base of a bank of yellowish-white material, was less saline, containing only 0.167 per cent of salts, chiefly sodium bicarbonate and sodium sulphate. The boron content of all three samples, 0.44, 0.24, and 1.24 parts per million, was so low that this constituent is not to be considered as limiting plant growth in these soils. As compared with agricultural soils, the salinity of samples 1 and 2 would be regarded as high but not too high to prevent the growth of many species of plants. Sample No. 3 would be considered not saline.

These analyses do not disclose either the presence or the absence of substances that explain the occurrence of Gilmania on these areas.

The seeds of some of the desert annuals germinate so promptly when the ground is moistened that the young plants sometimes blossom and produce seed from a single good rain, before the ground has become dry enough to kill the plants. Occasionally one of these annuals, a *Cryptantha*, for example, produces seed when it is less than half an inch in height. From Mr. Gilman's observations in 1935 it is his tentative opinion that *Gilmania* can

not do this, but that at least two rains, properly timed, are necessary to enable the plant to produce seeds. In the season of 1935 the rainfall in the bottom of Death Valley was unusually heavy. The autumn and winter rains up to January 5, 1935, had totaled 0.89 inch. On January 5 there was a rainfall of 0.27 inch, on February 4, 0.72 inch, and on March 2, 0.09 inch. Mr. Gilman believes that a few seeds of *Gilmania* germinated after the rain of February 4 and that the rain in March carried these plants through to maturity. Some of the plants reached a diameter of more than 10 inches and produced an abundance of seeds. Most of the plants found by Mr. Gilman in 1935, however, were tiny, consisting of only a small basal rosette of leaves, and they died without producing either branches or flowers. These small plants, Mr. Gilman believes, grew from seeds that germinated after the rain of March 2 and dried up in the rainless period that followed.

From these observations we have a fairly clear view of the reason for the rarity with which flowering specimens of *Gilmania* appear, because good rains, suitably timed, are not common in Death Valley. For example, up to February 6, 1936, there had been only 0.21 inch of rain in the bottom of Death Valley since March 2, 1935. This total of less than a quarter of an inch in nearly a year was made up of 0.10 inch in May, and 0.11 inch in December.

Apparently *Gilmania* is a plant in process of extinction through the extreme dryness of Death Valley. Its seeds, like those of many desert annuals, evidently are able to lie dormant in the ground for several years. Some of them germinate after a good rain if the temperature conditions are suitable for germination, but these germinated seeds do not produce fruiting plants, apparently, unless the seedlings are boosted to a suitable size and vigor by a second rain, adequate in amount and properly timed. In most years any little *Gilmania* plants that have been able to start will die before they produce seeds, from lack of a second rain. The continued existence of this species apparently depends on the dormancy of a sufficient number of seeds to carry it over unfavorable years to years of adequate and properly timed double rains. If Death Valley becomes drier and drier, and years with suitable double rains become more and more infrequent, the vitality of the old *Gilmania* seeds in the soil will ultimately be insufficient to span these longer periods of years when no new seeds are produced, and extinction, which is now a menace, will become a fact.

BOTANY.—*Notes on the Myristicaceae of Amazonian Brazil, with descriptions of new species.*[1] I. ADOLPHO DUCKE, Jardim Botanico, Rio de Janeiro. (Communicated by E. P. KILLIP.)

During my botanical trips in Amazonia I assembled a good number of plants of that interesting but not sufficiently studied family,

[1] Received February 15, 1936.

Myristicaceae, which must be considered one of the most important elements of the hylaea-flora, principally in the western half of this immense plain. The types of the new species are preserved in the herbarium of the Jardim Botanico of Rio de Janeiro; cotypes have been distributed among the principal institutions of Europe and America. Of these last, special mention may be made of the U. S. National Herbarium in Washington. The material sent to that herbarium was compared with the Myristicaceae in the herbarium of the New York Botanical Garden by Dr. A. C. Smith, for which I thank him very kindly. Wood samples accompanied by herbarium material of several species have been deposited at the Yale School of Forestry.

A part of the material examined was gathered by me when I was in the service of the late Dr. J. Huber, the eminent botanist, Director of the Pará Museum (Museu Goeldi); duplicates of that material are deposited in the Jardim Botanico, Rio de Janeiro.

Compsoneura

Compsoneura debilis (A. DC.) Warb. "Catinga" of Camanáos, Upper Rio Negro, State of Amazonas (*Ducke*, Herb. Jard. Bot. Rio 24445, distributed as a new species. This very small tree with pure white flowers is more like certain species of *Casearia* (Flacourtiaceae) than a Myristicacea. Adult leaves thick-coriaceous; ripe fruits orange-red; arilloid entire, purplish; seeds spotted, as in *C. sprucei* and *C. ulei*.

Compsoneura racemosa Ducke. São Paulo de Olivença (Rio Solimões); observed once (male tree).

Compsoneura capitellata (A. DC.) Warb. To this species, described from Eastern Peru, probably should be referred a small tree of the upland forest of São Paulo de Olivença, a Brazilian village near the Peruvian frontier (Herb. Jard. Bot. Rio 19803 and 23693, male trees, and 19576, female tree with flowers and fruits). The fruits, ellipsoid or less frequently nearly globose are up to 5 cm long and 3 cm thick, though not yet mature. They are green, glabrous, with a longitudinal keel at one side; their hard, ligneous pericarp is 3 mm thick when dry; the seed is not yet developed. These fruits are surely glabrous, with a longitudinal keel at one side; their hard, ligneous pericarp is 3 mm thick when dry; the seed is not yet developed. These fruits are surely very different from those of all other known Myristicaceae.

Compsoneura ulei Warb. This species must be placed, by its androecium, in the section *Coniostele* Warb.; its fruit resembles externally and internally that of *C. debilis* but is a little larger and of a pale yellow color, and its arilloid is white, instead of red as in all other Myristicaceae of which I have seen fruits. This very small tree, with long branches and yellowish

green flowers, is not very rare in the undergrowth of the upland forests of the Middle Amazon (western part of the State of Pará: Santarem, Lower and Middle Tapajoz, Obidos, Lower Trombetas; eastern half of the State of Amazonas: Maués, Manáos, Porto Velho; northwest of Matto Grosso: Santa Cruz of the Rio Jamary).

OSTEOPHLOEUM

OSTEOPHLOEUM PLATYSPERMUM (A. DC.) Warb. One of the most frequent and widely distributed Myristicaceae of the upland rain forest of Amazonian Brazil, from the mouths of the Amazon and the neighborhood of the capital of Pará to São Paulo de Olivença, not far from the Peruvian frontiers. It furnishes here, for this family, the largest trees, these sometimes more than 40 meters high, but only in the thickest stems do we find a very thin red heartwood.

IRYANTHERA Warb.

The species of this very natural genus are more difficult to classify than those of *Virola*, being nearly as numerous but much more uniform in their characters. Indument is always scarce, the leaves and the adult fruits being glabrous; the structure of the androecium is less variable than in *Virola*. Probably the fruits furnish the best characters to establish a natural arrangement of the species, but unfortunately most of these are only known in the male form. This genus is apparently restricted to the Amazonian hylaea (including the Guianas and the northwestern part of the State of Maranhão), where it is represented by a rather considerable number of species, though much less abundant in individuals than is *Virola;* it is one of the most characteristic elements of the hylaea-flora. All the species grow in upland virgin forest, where they prefer the neighborhood of small streamlets. All are known by the vernacular name "ucuhúba-rana" (false ucuhúba), those which furnish wood of good quality also as "punán."

Iryanthera dialyandra Ducke n. sp. Speciei *I. ulei* Warb. primo adspectu valde similis, at foliorum basi anguste rotundata vel subcordata, inflorescentiis, saepius e ramulorum parte inferiore ad folia delapsa, elongatis, usque 70 mm longis; ab ipsa omnibusque aliis speciebus hucusque notis differt antheris 3 ad columnae apicem sessilibus e basi liberis divergentibus. Planta feminea ignota. Arbor parva, partibus vegetativis glabra; foliorum petiolus brevis vel ad 18 mm longus, lamina vulgo ad 22 cm rarius 27 cm longa et ad 7–9 rarius 11.5 cm lata, saepius subobovato-elliptica colore et nervatione ut in specie citata; inflorescentiae tenuiter ferrugineo-puberulae vix ramosae, rhachi robusta; flores virescentes, e nodulis (vel ramulis minimis) fasciculati, pedicellis 3–6 mm longis, perigonio basi bracteolato 1.5–3 mm longo in alabastro plus minus obovato, anthesi tripartito, androecei columna gracili quam antherae multo longiore.

Habitat circa Manáos silva non inundabili ad ripas paludosas rivulorum, locis Estrada da Raiz inter Cachoeirinha et rivum Mindú (Herb. Jard. Bot. Rio 19578) et Estrada do Aleixo (Herb. Jard. Bot. Rio 24446), mensibus julio et augusto florifera, leg. A. Ducke.

The free anthers give to this species an isolated position within the genus. Many species are similar in leaves and sometimes also in the form of the inflorescences, but their anthers are entirely connate with the column of the androecium.

IRYANTHERA ULEI Warb. (*I. macrophylla* Warb., male, not female.) *I. macrophylla* Warb. (1897) is a mixture of *Myristica macrophylla* Spruce ex Benth. (a plant which, according to the descriptions, would be remarkable by its very large leaves but which is known only in female herbarium material with anomalous fruits) and of *Schwacke* 595 (=3532), a male plant of which I examined herbarium specimens in the Museu Nacional of Rio de Janeiro. A cotype of *I. ulei* (Rio Juruá-Miry, Acre Territory, *Ule* 5724) corresponds exactly with Schwacke's plant, collected at Manáos. I found, near this city, a third individual evidently conspecific with both the last mentioned plants. It was a small upland forest tree, growing at the swampy margins of a streamlet near the Estrada do Aleixo (Herb. Jard. Bot. Rio 24456).

The leaves of *I. ulei* reach rarely 25 cm in length, their average size being only 20 cm; they are thick but very fragile. The inflorescences are remarkably short; the column of the androecium, though variable in length, always exceeds the length of the anthers.

This species may be mistaken for many others, as for instance *I. dialyanthera*, but the elongate inflorescences and the form of the androecium of the latter are distinctive.

Iryanthera polyneura Ducke, n. sp. Speciebus *I. ulei*, *dialyandra*, *longiflora*, *paraensis* et *lancifolia* affinis, ab omnibus differt foliorum costis secundariis utrinque 28–32, inflorescentiis masculis (solis notis) 15–25 mm longis, simplicibus, pedunculo (brevissimo vel ad 6 mm longo) et rhachi crassis, florum fasciculis multifloris in inflorescentia dense agglomeratis, dense rufo-velutinis. Arbor mediocris ramulis superne tenuiter cano-tomentellis, foliis adultis glabris petiolo 15–20 mm longo, lamina 20–29 cm longa et 6–11 cm lata, basi obtusa vel anguste rotundata, apice vulgo abrupte acute acuminata, basi et apice saepe complicata, crasse coriacea fragili, utrinque granulosa, costis secundariis supra impressis subtus prominentibus, ante marginem arcuato-conjunctis, venulis non conspicuis. Flores viridiferruginei, ante anthesin subglobosi vix ultra 1 mm diametro, anthesi profunde trilobi intus glabri, androecei columna brevi quam antherae (6, perfecte adnatae, breves) vix longiore.

Habitat silva non inundabili circa Fontebôa (Rio Solimões, civ. Amazonas), 4–9–1929 leg. A. Ducke (Herb. Jard. Bot. Rio 24454).

Very similar, at the first glance, to many other species with thick but very fragile leaves; it differs, however, from all others by the more numerous lateral ribs of the leaves. The very short and dense inflorescences may be anomalous; in *I. lancifolia* we find similar inflorescences beyond the more numerous inflorescences of elongate form which evidently represent the normal type. *I. ulei* Warb. has very short and dense male inflorescences, but its leaves have only 14 to 18 lateral ribs.

Iryanthera longiflora Ducke, n. sp. Speciei *I. ulei* partibus vegetativis simillima, solum ramulorum tomento diutius persistente. Inflorescentiae masculae (solae notae) in ramulorum parte inferiore infra folia numerosae, binae, 6–12 cm longae, sat flexuosae, super basin pauciramosae vel (praeter nodulos floriferos interdum longe pedunculatos) simplices, partibus omnibus tenuiter rufo-ferrugineo-puberulis, nodulis vel ramulis floriferis modice distantibus multifloris; flores brunnescenti-virides, pedicello 5–8 mm longo tenui, bracteola parva pilosa, perianthio ante anthesin obovato-oblongo ad 3 mm longo vix 2 mm lato, anthesi oblongo-ureolato vix ad 1/3 ab apice trilobo, intus glabro, androecei columna cylindrica tenui quam antherae perfecte adnatae multo longiore. Arbor mediocris ramulis crassis superne cano-tomentellis, foliorum glabrorum petiolo 1–2 cm longo, lamina 20–30 cm longa et 5.5–9.5 cm lata, oblongo-elliptica vel lanceolato-oblonga, basi obtusa vel acutiuscula, apice acuta vel brevissime acuminata, crasse coriacea fragili, siccitate supre fusca subtus rufo-ferruginea, supra parum subtus vix nitida, utrinque (subtus fortius) granulosa, costis secundariis utrinque 15–20, longe ante marginem arcuato-conjunctis, supra impressis subtus fortiter prominentibus, venulis non conspicuis.

Habitat silva terris altis secus flumen Purús inter Boca do Acre et Monteverde, civitate Amazonas, 10–3–1933 leg. A. Ducke (Herb. Jard Bot. Rio 24457).

The leaves are like those of *I. ulei*, but the inflorescences and their insertion, as well as the flowers, are very different. In comparison with the other species with large and thick but very fragile leaves, *I. polyneura* has the nervures of the leaves much more numerous and the inflorescences very short and dense; *I. dialyandra* has the anthers not connate, divergent; *I. paraensis* has very elongate and thin inflorescences and very small flowers; *I. lancifolia* has the nervures of the leaves very faint; and all these species have smaller and more or less globose flowers. Finally, in *I. densiflora* the flowers have a somewhat elongate form, but they are shorter than in the others and the inflorescences are simple and dense; the leaves of this species are, however, very different.

Iryanthera lancifolia Ducke, n. sp. Affinis speciebus aliis foliis magnis crassis coriaceis fragilibus fultis; differt ab *I. dialyandra* antheris 6 perfecte adnatis; ab *I. paraensis* inflorescentiis multum minus elongatis, robustioribus; ab *I. longiflora* inflorescentiis minus elongatis, non ramosis, floribus parvis; ab *I. ulei* inflorescentiis sat longis et floribus minoribus; ab *I. polyneura* costis secundariis foliorum multum minus numerosis et inflorescentiis sat longis; a speciebus citatis omnibus foliis magis lanceolatis costis secundariis in utraque pagina tenuissimis. Arbor 20–25 m alta, praeter innovationes glabra; foliorum petiolus 10–18 mm longus robustus canaliculatus, lamina 16–24 cm longa et 4–7 cm lata, saepissime oblongo-lanceolata vel lanceolata, basi obtusa vel subacuta, apice acuta vel breviter acuminata, crasse coriacea fragilis utrinque granulosa, supra fuscescens nitida, subtus ferruginescens subopaca, costa primaria valida subtus prominente, costis secundariis utrinque 14–18 supra tenuissime immersis subtus tenuissime prominulis. Inflorescentiae masculae fere omnes infra folia e ramuli parte vetustiore, binae, vulgo 3–7 cm longae rarius breves (abnormes?), simplices, nodulis floriferis vulgo sat approximatis, rhachi crassiuscula tenuiter puber-

ula; flores viridi-ferruginei, in nodulo plures fasciculati, cum pedicello (brevi vel usque 5 mm longo, tenui) et bracteola (parva) dense rufo-velutini, perianthio ante anthesin subgloboso vix ultra 1 mm in diametro, anthesi profunde trilobo intus glabro, androecei columna brevi quam antherae 6 parvae perfecte adnatae parum longiore. Arbor feminea ignota.

Habitat prope Manáos silva non inundabili inter Estrada da Raiz et Igarapé Mindú, 13–7–1932 leg. A. Ducke (Herb. Jard. Bot. Rio 24553).

IRYANTHERA PARAENSIS Huber (*I. elongata* Huber). Nos. 429 and 542, male and female, of Dr. Sandwith's British Guiana collection are not at all different from the plants of Brazilian Amazonia. This species is distributed in the hylaea from the vicinity of the Atlantic as far as the Upper Amazon (Fontebôa and Tonantins). Kuhlmann found it in northwestern Matto Grosso between Pimenta Bueno and Riozinho (Herb. Comm. Rondon 1974). It is distinguished from *I. hostmannii* by the frequently larger leaves, the very elongate thin and flexuous male inflorescences, the very small flowers, and a very short androecium column.

IRYANTHERA HOSTMANNII (Benth.) Warb. This species from the Guianas and the Upper Rio Negro of Venezuela has not been found in Brazil. I have seen a fruiting specimen in the Museu Nacional (Maroni, French Guiana, *Melinon* 1861, without number); its leaves correspond exactly with the drawing in Warburg's monograph, plate 4; one of its two fruits resembles the fruit of the same plate, but the other has an almost triquetrous form, reminding one of the fruit of *I. tricornis*.

IRYANTHERA DENSIFLORA Huber. Readily recognized by its simple and dense inflorescences with relatively large flowers. A tree of the very moist upland forest from the Amazon estuary (islands of Breves and Gurupá), the region of the railway between Belem do Pará and Bragança (Peixeboi), and the Middle Tapajoz (S. Luiz, at the foot of the lowest rapids).

Iryanthera coriacea Ducke, n. sp. Arbor parva, praeter innovationes tenuiter rufo-tomentellas glabra. Foliorum distichorum petiolus 12–17 mm longus robustus profunde canaliculatus; lamina 13–20 cm longa 4.5–7 cm lata, obovato-lanceolato-oblonga vel -elliptica, basi anguste rotundato-obtusa complicata, apice sensim vel subabrupte modice longe acuminata, crasse et firme coriacea, utrinque nitida, subtus aliquanto pallidior et granuloso-rugulosa, costa mediana utrinque prominente subtus basi crassa, costis lateralibus utrinque 15–18 ante marginem arcuato-anastomosantibus supra fortiter impressis subtus tenuiter prominulis vel subimpressiusculis, venulis reticulatis impressis supra bene conspicuis. Inflorescentiae masculae super petiolorum insertiones vulgo binae, usque ad 8 cm longae, simplices, substrictae vel arcuatae rarius subflexuosae, cum floribus tenuiter rufo-sericeae; flores e nodulis vel ramulis brevissimis fasciculati, in fasciculo vulgo plurimi, pedicellis 2–4 mm longis tenuibus, perianthio basi bracteola squamiformi munito, ante anthesin subtriquetro-ovato vel subgloboso diametro ad 1.5 mm, anthesi aperto 3 mm lato usque ad medium obtuse trilobo, intus glabro, androecei columna robusta superne dilatata, antheris 6 perfecte adnatis plus minus aequilonga. Planta feminea ignota.

Habitat circa Manáos loco Estrada do Aleixo silva humosa humida non inundabili, 16–5–1933 leg. A. Ducke (Herb. Jard. Bot. Rio 24451).

Remarkable by its thick and hard but resistant leaves (not fragile as those of *I. ulei, dialyandra, paraensis* etc.), with the lateral ribs deeply immersed on the upper side and weakly prominent beneath. The inflorescences are rather elongate, simple, with very small flowers.

Iryanthera elliptica Ducke, n. sp. Arbor 30-metralis trunco robusto cylindrico, praeter innovationes rufo-sericeas glabra. Foliorum petiolus 8–14 mm longus robustus canaliculatus; lamina 7.5–12.5 cm longa et 4–5.5 cm lata, plus minus elliptica rarius oblongo- vel obovato-elliptica, basi rotundata vel obtusa complicata, apice abrupte breviter vel modice longe acuminata, sat crasse et dure coriacea, utrinque nitidula, subtus granulosa et pallidior vel ferruginescens, costa mediana subtus mediocriter crassa, costis secundariis in utroque latere tenuissime impressis plus minus obsoletis, venulis inconspicuis. Inflorescentiae masculae praesertim in ramulorum parte vetustiore supra axillas foliorum jam delapsorum binae, usque ad 8 cm longae, vulgo parum vel modice flexuosae, sat dense rufo-sericeo-puberulae, simplices vel supra basin ramosae; flores flavido-virides e nodulis vel ramulis brevibus modice distantibus fasciculati, sat numerosi in fasciculo, pedicellis ad 3 mm longis tenuibus, bracteola dense rufo-pilosula, perianthio ante anthesin subtriquetro-obovato vix ad 1.5 mm longo demum profunde trilobo extus parce puberulo intus glabro, androecei columna cylindrica quam antherae 6 perfecte adnatae multo longiore. Planta feminea ignota.
Habitat prope Manáos in silvis terris altis ultra Flores, 1–7–1932, leg. A. Ducke (Herb. Jard. Bot. Rio 24450).

This species resembles at the first glance *I. sagotiana* but may be recognized by its coriaceous leaves, which are nearly as thick and as hard as those of *I. coriacea* (through a little more fragile) and are of elliptic form and very much smaller. It is distinguished from both by the much longer androecium column.

IRYANTHERA JURUENSIS Warb. I have in hand a great number of herbarium specimens, among them a cotype (*Ule* 5460). From these I cannot distinguish no. 7103 of the Herb. Amaz. Mus. Pará, which is the type of *I. grandiflora* Huber for the staminate flowers. Huber's species would seem to differ from *I. juruensis* chiefly by its longer flowers, but the same twig has numerous smaller (normal) flowers, which do not exceed the dimensions of true *I. juruensis*. The column of the androecium in this species is at least as long as the anthers; in this particular Huber's diagnosis of *I. grandiflora* is incorrect. The fruit is cylindric with rounded extremities, transversal in relation to the peduncle, and is slightly larger than that of *I. paraensis*. The species *I. juruensis* is spread through the upland forests of the Middle and Upper Amazon, from Santarem, Obidos, and the middle courses of Tapajoz and Trombetas to the Lower Japurá and the Upper Juruá (Acre Territory). Krukoff collected it at the headwaters of the Rio Machado (northwestern Matto Grosso). To this species belong nos. 8553 and 8749 of the Herb. Amaz. Mus. Pará (Faro and Serra de Parintins) and no. 23682 of the Herb.

Jard. Bot. Rio (Lower Madeira), all distributed under the name *I. sagotiana* by Huber and by myself.

Iryanthera grandis Ducke, n. sp. Arbor ultra 30 m alta, trunco cylindrico robusto, ligno interiore amplo rufo-brunneo bono, glabra, innovationibus rufo-tomentellis. Foliorum petiolus usque 2 cm longus supra canaliculatus, lamina 13–25 cm longa, 5–7.5 cm lata, obovato- vel rarius sublanceolato-oblonga, basi anguste rotundata vel breviter obtusa saepe complicata, rarius subcordata, apice brevissime et vulgo obtuse acuminata, adulta subcoriacea fragilis, supra nitidula, subtus subopaca et parum pallidior quam supra, costa mediana subtus crassa, costis lateralibus utrinque 16–20 ante marginem plus minus evanescentibus, subtus tenuiter prominulis, venulis nullis vel in utraque pagina tenuissime immersis. Inflorescentiae masculae super petiolorum insertiones saepius binae, vulgo 5–12 cm longae, rhachi apicem versus attenuata in vivis molli et flexuosa, tenuiter rufo-ferrugineo-puberula; flores circa apices nodulorum vel ramulorum brevium modice distantum fasciculati, cum pedicello (ad 2 mm longo, tenui) et bracteola (parva, sub ipso flore inserta) densius rufo-ferrugineo-sericei, perianthio intus glabro, in alabastro subtriangulari-globoso, anthesi aperto vix ultra 1 mm diametro late campanulato profunde tripartito, androecei columna brevissima infra angustata, antheris vulgo 6 albidis adnatis subaequali vel parum breviore. Inflorescentiae femineae fructiferae solae visae, e trunci nodis vix ultra 3 cm longae; fructus maturus breviter crasse stipitatus, circa 4 cm altus et crassus, circa 5 cm latus, demum in valvas duas semiglobosas dehiscens, pericarpio lignoso durissimo circa 1 cm crasso, glabro, arillodio purpureo integro, semine 3.5–4 cm lato et fere 2 cm alto et crasso, testa laxe sulcato-reticulata, albumine non ruminato.

Habitat circa lacum José-Assú prope Parintins (civ. Amazonas), silva non inundabili, arbor mascula, 15–9–1932 leg. A. Ducke cum ligno no. 151, (Herb. Jard. Bot. Rio 24447); in silvis collinis prope cataractas Mangabal medii fluminis Tapajoz (civ. Pará), arbor feminea fructifera, 10–12–1919 leg. Ducke (Herb. Jard. Bot. Rio 2896). "Ucuhúba-rana" vel "punán" appellatur.

This species is allied to *I. tricornis* Ducke, which furnishes also a very valuable wood. The leaves, however, are much larger, glabrous, with more numerous lateral ribs; the male inflorescences are shorter and stouter, with less distant floriferous nodes; the fruit has a very different form, being remarkable for its size and its ligneous, exceedingly thick pericarp.

IRYANTHERA TRICORNIS Ducke, Tropical Woods No. 31, 11. 1932; Archiv. Jard. Bot. Rio **6**: 9. 1933. This species, the "punán" of the Solimões river (Fontebôa, S. Paulo de Olivença) is a tree 18 to 30 meters high, with cylindric stem which furnishes a highly esteemed reddish brown, afterwards dark brown heartwood. It grows in the humid upland forest. It can be recognized by the medium-sized obovate leaves, the thin and flexuous male inflorescences, and the three-horned fruits, the form of which is more exaggerated than that of the fruits of *I. hostmanni*.

IRYANTHERA SAGOTIANA (Benth.) Warb. A small or scarcely medium-sized tree, frequent in the upland forests from the environs of Belem do

Pará to Santa Izabel at the Bragança railway, but not yet observed elsewhere in Amazonia. Nos. 8553 and 8749 of the Herb. Amaz. Mus. Pará (from Faro and Serra de Parintins), as well as Herb. Jard. Bot. Rio 23682 (of the Lower Madeira), are evidently *I. juruensis* Warb. The present species seems to be limited to that part of the hylaea near the Atlantic.

IRYANTHERA LAEVIS Mgf. A tree of medium size, collected by myself in the upland forests in the State of Amazonas near Manáos (Herb. Jard. Bot. Rio 24459), Fontebôa (Herb. Jard. Bot. Rio 24458), and Parintins (Lake Uaicurapá, Herb. Jard. Bot. Rio 24455). This species was previously collected in Amazonian Peru by Tessmann (type) and by Killip and Smith. Our herbarium specimens were distributed as a new species, but Dr. Smith has established their identity with *I. laevis*, an insufficiently described species of which he has seen a typical specimen.

The leaves of *I. laevis* resemble in color and nearly also in texture those of *I. sagotiana*, but in many other characters this species is more like *I. juruensis*, from which it differs, however, by the very insignificant nervures of the leaves and by the ample male inflorescences. The flowers though variable in size, are among the largest in this genus. A very good character is the abundance of the pale lenticels, which are never completely absent on the young branchlets and sometimes are present even on the rachis of the inflorescences; I never observed them in any other species of this genus.

Iryanthera obovata Ducke, n. sp. Arbor mediocris, partibus vegetativis praeter innovationes tenuiter puberulas omnino glabris. Foliorum petiolus 1–1.5 cm longus validus supra canaliculatus; lamina 8–11 cm longa et 3.5–6 cm lata, obovata vel oblongo-obovata, basi obtusa vel subacuta, apice vulgo late obtusa rarius rotundata vel brevissime obtuse acuminata, subelastice coriacea, margine subtus lineiformi saepe revoluto, concolor et vix nitidula (adulta subglauca), praesertim subtus dense granulosa, costa mediana utrinque prominente subtus basi crassa, costis lateralibus nullis vel supra tenuissime et obsolete impressis, venulis nullis. Inflorescentiae masculae (solae notae) super axillas foliorum (interdum delapsorum) binae vel solitariae, breves vel saepius usque ad 8 cm longae, simplices vel super basin pauciramosae, graciles, tenuiter ferrugineo-puberulae, florum fasciculis e ramulo brevissimo vel nodulo; flores in fasciculo bini vel pauci, virescentes, pedicellis 5–9 mm longis tenuissimis, perianthio basi bractea squamiformi breviter et longius pilosula, in alabastro subgloboso-ellipsoideo, anthesi circa 2.5 mm diametro, ad medium obtuse trilobo, extus appresse puberulo intus glabro, columna androecei e basi dilatata anguste cylindrica, antheris 6 omnino adnatis longiore.

Habitat in silvis "catinga" in regione Rio Negro superioris (civit. Amazonas) prope Camanáos (Herb. Jard. Bot. Rio 24452) et circa affluentem Curicuriary (Herb. Jard. Bot. Rio 24462), Octobre florens, leg. A. Ducke.

The present species can be recognized by its obovate and coriaceous leaves, nearly destitute of nervures, and by its rather elongate but few dense inflorescences with long and very thin pedicels. It resembles, at first glance, *Osteophloeum platyspermum*, but the leaves are shorter, more coriaceous, and

without nerves, and the inflorescences are different; these, in our new species, resemble a little the inflorescences of *Compsoneura ulei*.

IRYANTHERA PARADOXA (Schwacke) Warb. This species seems to have been found only once (*Schwacke* 3736=575, Museu Nacional Rio de Janeiro). It must be rare, because I have never observed it near Manáos, the type locality, where I collected no less than six of its congeners. It should be easily recognized from the diagnosis and illustrations in Warburg's monograph.

Obituary

ANDREW NELSON CAUDELL, entomologist of the Bureau of Entomology and Plant Quarantine and custodian of Orthoptera at the U. S. National Museum, died at his home, 605 Keefer Place, Washington, D.C., March 1, 1936. He was born August 18, 1872, at Indianapolis, Indiana. After receiving the Bachelor of Science degree at Oklahoma Agricultural and Mechanical College in 1897, and a year's study at Massachusetts Agricultural College, he joined the Bureau of Entomology of the U. S. Department of Agriculture in 1898.

Mr. Caudell's scientific work was concerned chiefly with the natural history and classification of the Orthoptera about which he wrote numerous papers, one of the last (unpublished) being in joint authorship on the Orthoptera of the District of Columbia and vicinity. His hobby was philately to which he also contributed important papers.

Mr. Caudell was a member of the American Association for the Advancement of Science, Association of Economic Entomologists, Entomological Society of Washington, Washington Academy of Sciences, and the American Philatelic Society.